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# Lake Eufaula, Haskel, Okmulgee, McIntosh, and Pittsburg Counties Oklahoma

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

Mar 77

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# NATIONAL EUTROPHICATION SURVEY
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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

LAKE EUFAULA

HASKELL, OKMULGEE, MCINTOSH, AND

PITTSBURG COUNTIES

OKLAHOMA

EPA REGION VI

WORKING PAPER NO. 580

WITH THE COOPERATION OF THE

OKLAHOMA DEPARTMENT OF POLLUTION CONTROL

AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

# REPORT ON LAKE EUFAULA

## HASKELL, OKMULGEE, MCINTOSH, AND PITTSBURG COUNTIES, OKLAHOMA

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

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March 1977

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# FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

## OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

## ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

## LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis V. Milligan and Major James O. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

# NATIONAL EUTROPHICATION SURVEY
## STUDY LAKES
## STATE OF OKLAHOMA

| LAKE NAME | COUNTY |
|---|---|
| Altus Reservoir | Greer, Kiowa |
| Arbuckle Lake | Murray |
| Lake Ellsworth | Caddo, Comanche |
| Lake Eufaula | Haskell, McIntosh, Okmulgee, Pittsburg |
| Fort Cobb Reservoir | Caddo |
| Fort Supply Reservoir | Woodward |
| Foss Dam Reservoir | Custer |
| Lake Frances | Adair |
| Grand Lake O' The Cherokees | Mayes, Delaware, Craig, Ottowa |
| Lake Hefner | Oklahoma |
| Keystone Reservoir | Tulsa, Creek, Osage, Pawnee |
| Oologah Lake | Nowata, Rogers |
| Tenkiller Ferry Reservoir | Cherokee, Sequoyah |
| Lake Thunderbird | Cleveland |
| Wister Reservoir | Leflore |

EUFAULA RESERVOIR

REPORT ON LAKE EUFAULA, OKLAHOMA
STORET NO. 4004

I. CONCLUSIONS

A. Trophic Condition:

Based upon survey data, Lake Eufaula is considered eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values in the lake ranged from 0.9 µg/l in June to 25.4 µg/l in October with a mean of 4.4 µg/l. Potential for primary production as measured by algal assay control yield was high. Of the 16 Oklahoma lakes sampled (including Lake Texoma), only 3 had higher median total phosphorus levels (0.081 mg/l), 5 had higher median inorganic nitrogen values (0.405 mg/l), and 5 had higher median orthophosphorus levels (0.029 mg/l) than Lake Eufaula.

Field limnologists did not note any phytoplankton blooms or widespread macrophytes. However, it was noted that the lake was highly turbid on all sampling occasions; the low Secchi disc transparencies (range of 0.2 to 1.1 m) suggest that primary productivity in the lake is light limited.

B. Rate-Limiting Nutrient:

The algal assay results indicate that nitrogen was the primary limiting nutrient in Lake Eufaula during the spring sampling period and phosphorus was limiting during fall. The lake data suggest nitrogen limitation in the lake on all four sampling occasions. However, the low light penetration is likely a major, if not overriding, consideration in the limitation of productivity in Lake Eufaula.

C. Nutrient Controllability:

1. Point sources -

During the sampling year, point sources contributed 24.8% of the total phosphorus load to Lake Eufaula. The South Oklahoma City plant contributed 22.2% of the total load, the city of Okmulgee, 1.1%, and the remaining 15 municipal plants impacting the lake contributed about 1.5%.

The annual total phosphorus loading of 4.16 g $P/m^2/yr$ is about six times that proposed by Vollenweider (1975) as a "eutrophic" loading. Although elimination of all known point source contributions would not reduce this loading to Vollenweider's "eutrophic" level, it would reduce the high potential for occurrence of nuisance conditions which only appears to be held in check presently by the very limited light penetration.

2. Nonpoint sources -

Nonpoint sources were found to contribute 75.2% of the total phosphorus load to Lake Eufaula in the 1974 sampling

year. The North Canadian River contributed 36.8% of the total load, Deep Fork contributed 12.5%, the Canadian River, 10.6%, and ungaged drainage areas were estimated to contribute 6.2% of the total. Substantial unmeasured point source contributions are included in these calculated tributary loads. The Oklahoma Department of Pollution Control (1975a) reports that the North Canadian River below Oklahoma City is of low quality due to the introduction of municipal, industrial, and oilfield wastes, and that this degraded quality continues throughout the rest of the stream course. This agency further states (1975a,b) that the Deep Fork and Canadian River drainage areas are also of poor quality as they enter Lake Eufaula, primarily due to highly mineralized oilfield brines. Examination of current land use practices in the Eufaula drainage basin and measurement of additional point sources may provide answers to further nutrient reductions in the reservoir.

## II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by means as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 414.81 $km^2$.
2. Mean depth: 10.1 meters.
3. Maximum depth: 26.5 meters.
4. Volume: 4,189.581 x 106 $m^3$.
5. Mean hydraulic retention time: 309 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

| Name | Drainage area(km²) | Mean flow (m³/sec) |
|---|---|---|
| A-2 Canadian River | 59,961.1 | 51.10 |
| C-1 Gaines Creek | 330.7 | 3.18 |
| G-1 North Canadian River | 24,322.7 | 80.01 |
| H-1 Deep Fork | 5,327.6 | 23.17 |
| Minor tributaries and immediate drainage - | 7,596.1 | 84.07 |
| Totals | 97,544.2 | 181.73 |
| 2. Outlet - A-1 Canadian River | 97,958.9 | 196.96 |

C. Precipitation:

1. Year of sampling: 141.7 cm.
2. Mean annual: 107.4 cm.

## III. LAKE WATER QUALITY SUMMARY

Lake Eufaula was sampled four times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from nine stations on the lake and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll *a* analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths (expressed in meters) sampled are listed below:

| Station Number | Maximum Depth |
|---|---|
| 01 | 25.0 |
| 02 | 19.8 |
| 03 | 18.3 |
| 04 | 19.8 |
| 05 | 13.7 |
| 06 | 6.1 |
| 07 | 18.3 |
| 08 | 10.7 |
| 09 | 14.3 |

For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll *a* determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

| | | | | | | | | | | |
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B. Biological Characteristics:

1. Phytoplankton -

| Sampling Date | Dominant Genera | Algal Units per ml |
|---|---|---|
| 04/01/74 | 1. Chroomonas | 355 |
| | 2. Scenedesmus | 355 |
| | 3. Cyclotella | 133 |
| | 4. Ankistrodesmus | 89 |
| | 5. Skeletonema | 89 |
| | Other genera | 532 |
| | Total | 1,553 |
| 06/13/74 | 1. Chroomonas | 351 |
| | 2. Stephanodiscus | 292 |
| | 3. Cryptomonas | 264 |
| | 4. Chlamydomonas | 88 |
| | 5. Carteria | 58 |
| | Other genera | 321 |
| | Total | 1,373 |
| 08/20/74 | 1. Melosira | 1,097 |
| | 2. Stephanodiscus | 240 |
| | 3. Chroomonas | 206 |
| | 4. Anabaena | 69 |
| | 5. Schroederia | 69 |
| | Other genera | 306 |
| | Total | 1,987 |
| 10/22/74 | 1. Chroomonas | 617 |
| | 2. Chlamydomonas | 371 |
| | 3. Centric diatom | 297 |
| | 4. Cryptomonas | 223 |
| | 5. Melosira | 99 |
| | Other genera | 49 |
| | Total | 1,856 |

F. Chlorophyll a -

| Sampling Date | Station Number | Chlorophyll a (ug/l) |
|---|---|---|
| 04/01/74 | 01 | 1.8 |
| | 02 | 1.5 |
| | 03 | 2.1 |
| | 04 | 1.5 |
| | 05 | 1.7 |
| | 06 | 12.1 |
| | 07 | 4.6 |
| | 08 | 13.6 |
| | 09 | 7.5 |
| 06/13/74 | 01 | 2.3 |
| | 02 | 2.5 |
| | 03 | 4.8 |
| | 04 | 1.2 |
| | 05 | 0.9 |
| | 06 | 1.6 |
| | 07 | 1.2 |
| | 08 | 2.0 |
| | 09 | 1.8 |
| 08/20/74 | 01 | 4.2 |
| | 02 | 4.7 |
| | 03 | 7.6 |
| | 04 | 2.1 |
| | 05 | 2.0 |
| | 06 | 3.3 |
| | 07 | 5.2 |
| | 08 | 6.0 |
| | 09 | 2.0 |
| 10/22/74 | 01 | 1.8 |
| | 02 | 1.2 |
| | 03 | 1.4 |
| | 04 | 2.3 |
| | 05 | 4.2 |
| | 06 | 25.4 |
| | 07 | 4.6 |
| | 08 | 5.8 |
| | 09 | 2.4 |

C. Limiting Nutrient Study:

1. Autoclaved, Filtered, and nutrient spiked -

| Spike(mg/l) | Ortho P Conc.(mg/l) | Inorganic N Conc.(mg/l) | Maximum Yield (mg/l dry wt.) |
|---|---|---|---|
| a. 04/01/74 - Stations 01-03 | | | |
| Control | 0.035 | 0.361 | 9.3 |
| 0.05 P | 0.085 | 0.361 | 9.6 |
| 0.05 P + 1.0 N | 0.085 | 1.361 | 31.4 |
| 1.00 N | 0.035 | 1.361 | 12.1 |
| Stations 04-06 | | | |
| Control | 0.030 | 0.425 | 6.9 |
| 0.05 P | 0.080 | 0.425 | 10.8 |
| 0.05 P + 1.0 N | 0.080 | 1.425 | 26.1 |
| 1.00 N | 0.030 | 1.425 | 10.6 |
| Stations 07-09 | | | |
| Control | 0.050 | 0.420 | 13.2 |
| 0.05 P | 0.100 | 0.420 | 14.4 |
| 0.05 P + 1.0 N | 0.100 | 1.420 | 29.1 |
| 1.00 N | 0.050 | 1.420 | 20.1 |
| b. 10/22/74 - Stations 01-04 | | | |
| Control | 0.013 | 0.199 | 1.1 |
| 0.05 P | 0.063 | 0.199 | 4.6 |
| 0.05 P + 1.0 N | 0.063 | 1.199 | 20.6 |
| 1.00 N | 0.013 | 1.199 | 1.2 |
| Stations 05,06 | | | |
| Control | 0.020 | 0.176 | 3.1 |
| 0.05 P | 0.070 | 0.176 | 6.4 |
| 0.05 P + 1.0 N | 0.070 | 1.176 | 23.0 |
| 1.00 N | 0.020 | 1.176 | 3.4 |

| Spike(mg/l) | Ortho P Conc.(mg/l) | Inorganic N Conc.(mg/l) | Maximum Yield (mg/l-dry wt.) |
|---|---|---|---|
| b. 10/22/74 (cont.) - Stations 07-09 | | | |
| Control | 0.021 | 0.104 | 2.6 |
| 0.05 P | 0.071 | 0.104 | 3.0 |
| 0.05 P + 1.0 N | 0.071 | 1.104 | 20.6 |
| 1.00 N | 0.021 | 1.104 | 9.0 |

c. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity in Lake Eufaula was extremely high at the time of spring sampling (04/01/74) and high during fall (10/22/74). In the spring assays for Stations 01-03 and 07-09, and the fall assay for Stations 07-09, there was a significant increase in yield over that of the control when nitrogen was added, indicating nitrogen limitation. In the spring, Stations 04-06 assay, significant response accompanied the addition of both phosphorus and nitrogen alone, suggesting near colimitation by the two nutrients. In the fall assays for Stations 01-06, phosphorus appeared to be the growth limiting nutrient. In all the assays, the simultaneous addition of both phosphorus and nitrogen resulted in maximum increases in yield.

The mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 13/1 or less on all sampling occasions, suggesting primary limitation by nitrogen in Lake Eufaula (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

## IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected at some tributary sites. Sampling was begun in November 1974, and was completed in October 1975.

Through an interagency agreement, stream flow estimates for the year of sampling an a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km$^2$/yr, in Gaines Creek at Station C-1, and multiplying the means by the ZZ area in km$^2$.

The operators of the V.A.D. McAlester, McAlester, Haileyville, Henryetta, Okmulgee, and South Oklahoma City wastewater treatment plants provided monthly effluent samples and corresponding flow data. Nutrient loads for the remaining wastewater treatment plants were estimated at 1.134 kg P and 3.401 kg N/capita/yr.

| | | |

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

| Source | kg P/yr | % of total |
|---|---|---|
| a. Tributaries (nonpoint load) - | | |
| A-2 Canadian River | 320,495 | 18.6 |
| C-1 Gaines River | 4,970 | 0.3 |
| D-1 North Canadian River | 635,120 | 36.8 |
| H-1 Deep Fork | 215,355 | 12.5 |
| b. Minor tributaries and immediate drainage (nonpoint load) - | 113,940 | 6.6 |
| c. Known municipal STP's - | | |
| N.A.D. McAlester | 535 | <0.1 |
| McAlester | 9,665 | 0.5 |
| Hatleyville | 95 | <0.1 |
| Eufaula | 3,120 | 0.2 |
| Oklahoma State Penitentiary | 1,475 | 0.1 |
| Krebs | 1,530 | 0.1 |
| Hartshorne | 1,135 | 0.1 |
| U.S. Navy Depot | 115 | <0.1 |
| Savannah | 565 | <0.1 |
| Dewar | 565 | <0.1 |
| Henryetta | 7,460 | 0.4 |
| Morris South | 325 | <0.1 |
| Morris N.W. | 980 | 0.1 |
| Okmulgee | 19,425 | 1.1 |
| South Oklahoma City | 383,030 | 22.2 |
| Pittsburg | 220 | <0.1 |
| Dustin | 115 | <0.1 |
| d. Septic tanks* - | 10 | <0.1 |
| e. Known industrial - See 1, page 13. | | |
| f. Direct precipitation** - | 7,260 | 0.4 |
| Totals | 1,726,900 | 100.0 |
| 2. Output - A-1 Canadian River | 1,084,280 | |
| 3. Net annual P accumulation - | 642,625 | |

*Estimate based on 25 lakeshore residences and 1 park.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

| Source | kg N/yr | % of total |
|---|---|---|
| a. Tributaries (nonpoint load) - | | |
| A-2 Canadian River | 4,136,980 | 37.4 |
| C-1 Gaines Creek | 66,120 | 0.6 |
| B-1 North Canadian River | 2,169,175 | 19.3 |
| H-1 Deep Fork | 1,514,930 | 13.5 |
| b. Minor tributaries and immediate drainage (nonpoint load) - | 1,944,600 | 17.3 |
| c. Known municipal STP's - | | |
| N.A.D. McAlester | 2,380 | <0.1 |
| McAlester | 22,765 | 0.2 |
| Hallsville | 235 | <0.1 |
| Eufaula | 9,355 | 0.1 |
| Oklahoma State Penitentiary | 4,420 | <0.1 |
| Krebs | 4,590 | <0.1 |
| Hartshorne | 3,400 | <0.1 |
| U.S. Navy Depot | 340 | <0.1 |
| Savannah | 1,700 | <0.1 |
| Dewar | 1,700 | <0.1 |
| Henryetta | 24,590 | 0.2 |
| Morris South | 980 | <0.1 |
| Morris N.W. | 2,935 | <0.1 |
| Okmulgee | 61,715 | 0.6 |
| South Oklahoma City | 736,175 | 6.7 |
| Pittsburg | 665 | <0.1 |
| Dustin | 340 | <0.1 |
| d. Septic tanks* - | 270 | <0.1 |
| e. Known industrial - See 1, page 13. | | |
| f. Direct precipitation** - | 447,830 | 4.0 |
| Totals | 11,215,190 | 100.0 |
| 2. Output - A-1 Canadian River | 10,392,320 | |
| 3. Net annual N accumulation - | 825,870 | |

*Estimate based on 25 lakeshore residences and 1 park.
**Estimated (see NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

| Tributary | kg P/km²/yr | kg N/km²/yr |
|---|---|---|
| Canadian River | 5 | 70 |
| Gaines Creek | 15 | 256 |
| North Canadian River | 26 | 89 |
| Deep Fork | 40 | 284 |

E. Mean Nutrient Concentrations in Ungaged Streams:

| Tributary | Mean Total P (mg/l) | Mean Total N (mg/l) |
|---|---|---|
| B-1 Longtown Creek | 0.025 | 0.909 |
| D-1 Brushy Creek | 0.245 | 1.207 |
| E-1 Coal Creek | 0.104 | 1.538 |
| F-1 Mill Creek | 0.080 | 1.694 |

Nutrient levels in tributaries D-1, E-1, and F-1 are all substantially higher than those in the unimpacted tributaries to Lake Eufaula. The inflated nutrient concentrations in Brushy Creek, D-1, are probably due to sewage treatment facility impact from the Pittsburg, Savannah, the U.S. Navy Ammunition Depot, Hartshorne, and Halleyville plants. Coal Creek, E-1, receives effluent from the McAlester and Oklahoma State Penitentiary plants.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

| | Total Yearly Phosphorus Loading ($g/m^2/yr$) |
|---|---|
| Estimated loading for Lake Lufaula | 4.16 |
| Vollenweider's "eutrophic" loading | 0.67 |
| Vollenweider's "oligotrophic" loading | 0.33 |

## IV. LITERATURE REVIEWED

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# VI. APPENDICES

## APPENDIX A
## CONVERSION FACTORS

## CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x $8.107 \times 10^{-4}$ = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

# APPENDIX B

# TRIBUTARY FLOW DATA

# APPENDIX C

# PHYSICAL AND CHEMICAL DATA

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# APPENDIX D

# TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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APPENDIX E

PARAMETRIC RANKINGS OF LAKES
SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

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